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ABSTRACT:

CHG DATE=19990617 STATUS=O> An improved method of and apparatus for electroerosively wire- cutting a workpiece (W) with a continuous, axially traveling elongate electrode (1) wherein (a) the elongate electrode is formed of a core wire of a magnetic material having an outer layer of electrically conductive material disposed thereon, and (b) a magnetic field, preferably in excess of 100 Gauss and preferably of AC or pulsed nature, is applied at 16 to the region of the machining gap defined between the traveling elongate electrode and the workpiece. The magnetic material is preferably of greater tensile strength and lesser electrical conductivity than the conductive material. Suggested electrode materials are, for the core, stainless steel and, for the outer layer, aluminium, copper, gold and silver.

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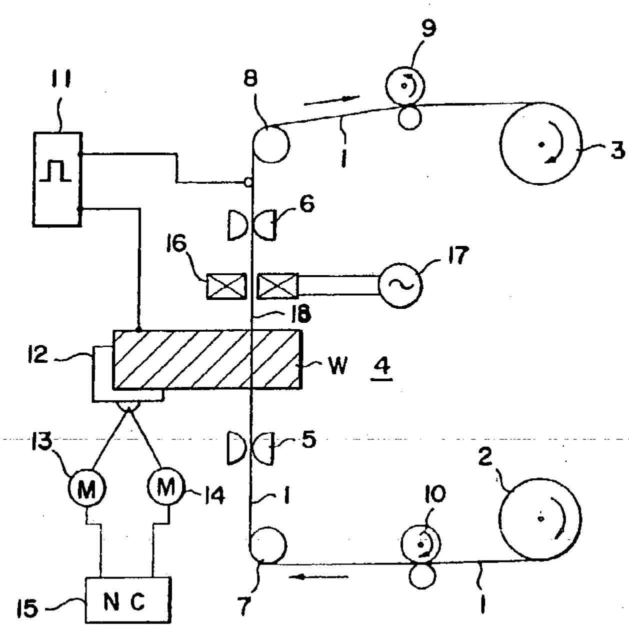
(54) Wire-cutting electroerosion machining method and apparatus

(57) An improved method of and apparatus for electroerosively wire-cutting a workpiece (W) with a continuous, axially traveling elongate electrode (1) wherein (a) the elongate electrode is formed of a core wire of a magnetic material having an outer layer of electrically conductive material disposed thereon, and (b) a magnetic field, preferably in excess of 100 Gauss and preferably of AC or pulsed nature, is applied at 16 to the region of the machining gap defined between the traveling elongate electrode and the workpiece. The magnetic material is preferably of greater tensile strength and lesser electrical conductivity than the conductive material. Suggested electrode materials are, for the core, stainless steel and, for the outer layer, aluminium, copper, gold and silver.

FIG. 1



The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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FIG. 1

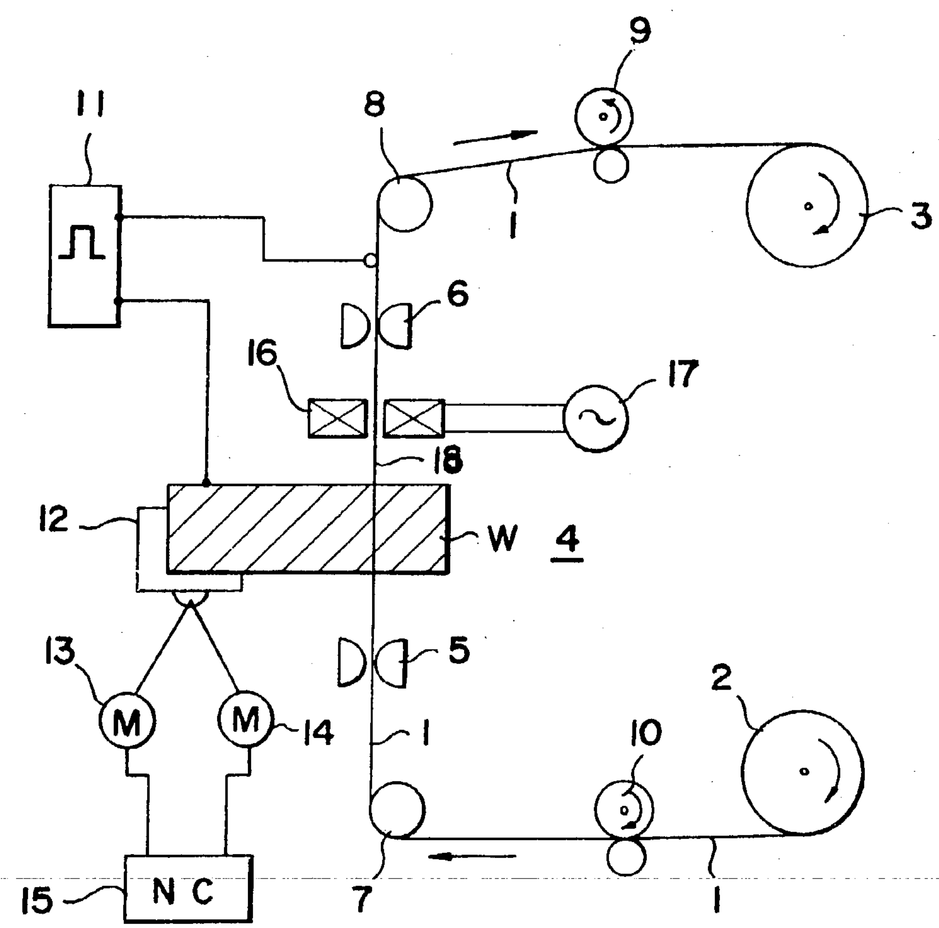


FIG. 2

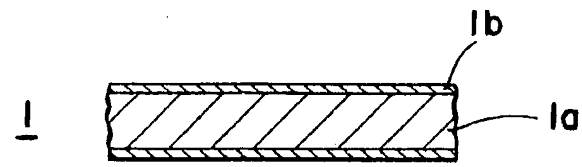


FIG. 3

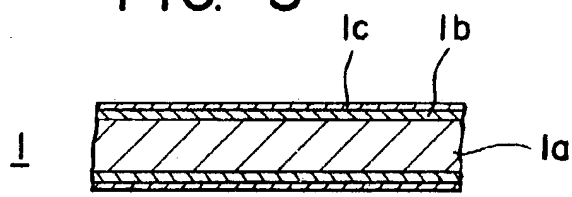
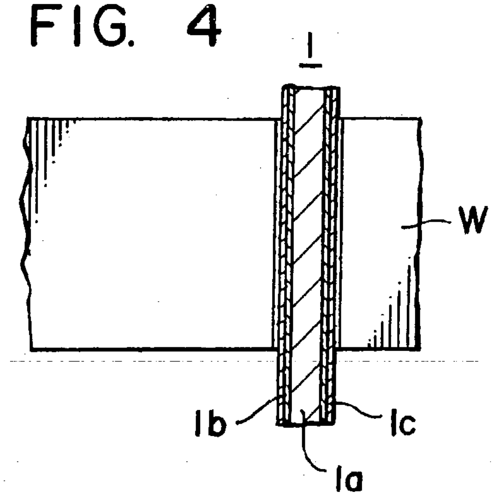


FIG. 4



SPECIFICATION

Wire-cutting electroerosion machining method and apparatus

The field to which the present invention relates is the art of electroerosively wire-cutting a workpiece with a continuous elongate electrode. The invention particularly relates to an improved electroerosive wire-cutting method and apparatus whereby both the efficiency and stability of cutting are increased.

In electroerosively wire-cutting a workpiece, a continuous wire, filamentary, bank-shaped or the like elongate electrode is axially transported from a supply side to a takeup side through a cutting region of the workpiece flushed with a machining liquid, i.e. distilled water or other liquid of dielectric nature, or a liquid electrolyte of a suitable conductivity. An electrical machining current is passed between the traveling elongate electrode and the workpiece through a machining gap formed therebetween to produce a succession of time-spaced electrical discharges and/or an intense electrolytic action through the liquid medium, thereby causing material to be electroerosively removed from the workpiece, while a relative displacement is effected between the traveling elongate electrode and the workpiece along a prescribed path to form a desired wire-cut pattern in the workpiece.

The cutting elongate electrode has hitherto been typically a wire of a metal or alloy such as copper or brass. These wires are readily available, and have good electrical and thermal conductivity and reasonable or ideal resistance to withstand electroerosive wear. These materials thus advantageously meet certain requirements for the electrode in the electroerosive wire-cutting process, but are relatively poor in tensile strength. However, that strength should desirably be high so as to withstand a greater tension applied to the electrode in the course of electroerosive wire-cutting. It should also be pointed out that these conventional materials are, without exception, nonmagnetic and not conductive to external magnetic fluxes.

The present invention seeks to provide a novel method of electroerosively wire-cutting a workpiece whereby much improvement is achieved as regards both cutting stability and efficiency; and in addition to provide an apparatus for carrying out that novel electroerosive wire-cutting method.

These and other objectives, which will become more readily apparent from the description which follows, are attained, in accordance with the present invention, in a first aspect thereof, by a method of electroerosively wire-cutting a workpiece with a continuous elongate electrode axially displaced from a supply side to a takeup side through a cutting zone of the workpiece flushed with a machining liquid, in which method an electric current is passed between the traveling elongate electrode and the workpiece through a machining gap to electroerosively remove material from the workpiece while a relative displacement other than the axial displacement of the elongate electrode is effected between the latter and the workpiece along a prescribed path to form a desired wire-cut pattern in the workpiece, and in which method (a) the elongate electrode is constituted by a wire composed of a magnetic or magnetically conductive material and having at least one layer of an electrically conductive material disposed thereon; and (b) a magnetic field is applied to the region of the machining gap.

The said magnetic material, which may be permanently magnetic or of high magnetic permeability or conductivity, should preferably have a high tensile strength, e.g greater than that of the said electrically conductive material. The latter should preferably have a high electrical conductivity such that where the said magnetic material is electrically conductive, the said conductivity is at any event greater than that of the said magnetic material. The electrically conductive material should, of course, have good electroerosion resistance so as to withstand electroerosive wear, and may be copper, silver, aluminium or gold, or an alloy of any of these metals or a combination of two or more of these metals, which may be electrochemically, chemically or otherwise deposited on the magnetic wire to form the said layer of high electrical (and thermal) conductivity. The magnetic wire may be composed of a ferrous material, and it has been found that a magnetic stainless steel is particularly suitable. The said magnetic field may be applied directly from the magnetic wire when composed of a permanently magnetized material, or be conveniently applied from an external magnetic field generating assembly. The magnetic field may alternatively be a field induced in the region of the machining gap by the passage of an electroerosive machining current between the elongate electrode and the workpiece.

In a second aspect, the invention provides an apparatus for electroerosively wire-cutting a workpiece with a continuous elongate electrode, which apparatus includes drive means for axially displacing the elongate electrode from a supply side to a takeup side through a cutting zone of the workpiece while applying a predetermined tension to the elongate electrode across the cutting zone, means for flushing the cutting zone with a machining liquid, a power supply for passing an electrical machining current between the traveling elongate electrode and the workpiece through a machining gap formed therebetween to electroerosively remove material from the workpiece, and machining feed means for effecting a relative displacement between the traveling elongate electrode and the workpiece along a prescribed path to form a desired wire-cut pattern in the workpiece, and in which apparatus (a) the elongate electrode is constituted as a wire composed of a magnetic material and having at least one layer of an electrically conductive material disposed thereon, and (b) there is provided a means for applying a magnetic field to

the region of said machining gap.

The means for applying the magnetic field may be coil means disposed, preferably in the vicinity or region of the cutting zone, and energized by an external power supply, either of AC or DC nature and either continuous or pulsed, for producing magnetic fluxes of an adjusted intensity to the region of the machining gap.

These and other features and advantages of the present invention will become more readily apparent from the following description of certain embodiments thereof taken with reference to the accompanying drawing in which:

FIG. 1 is a schematic diagram illustrating a wirecutting electroerosion machine arrangement incorporating the principles of the invention;

FIG. 2 is a sectional view diagrammatically illustrating a wire electrode for use in carrying out the present invention;

FIG. 3 is a sectional diagrammatic view of a further wire electrode for use in carrying out the invention; and

FIG. 4 is an elevational view in section diagrammatically illustrating a workpiece being machined with the wire electrode of FIG. 3.

Referring first of FIG. 1, a continuous electrode 1 in an elongate or wire form is shown axially transported from a supply side shown in the form of a feed drum 2 to a take-up side shown in the form of a collection drum 3 through a cutting region 4 in which an electrically conductive workpiece W is disposed. For defining the cutting zone 4 there are arranged a pair of machining guide members 5 and 6 which provide a linear stretch 18 of the wire electrode 1 for positioning it precisely in a machining relationship with the workpiece W. Further guide members 7 and 8 each in the form of a roll or roller are arranged upstream of the machining guide member 5 and downstream of the guide member 6, respectively, to change the direction of wire travel from the supply side 2 to the cutting zone 4 and from the latter to the takeup side 3. The axial displacement and transportation of the wire electrode 1 is effected, and an appropriate tension is established therein, by a traction drive, in the form of a pair of rollers 9 driven by a motor (not shown), acting in cooperation with a brake drive, in the form of a pair of rollers 10 driven by a motor (not shown).

A machining liquid (e.g. distilled water) of dielectric nature and/or electrolytic nature of a suitable conductivity or resistivity is supplied by nozzle means (not shown) to the cutting zone 4 to fill and flush the machining gap defined between the wire electrode 1 and the workpiece W. An electrical machining current, preferably in the form of a succession of pulses of precisely regulated parameters, is furnished from a power supply 11 and applied between the traveling wire-electrode 1 and the workpiece W to produce electrical discharges and/or an electrolytic action, thereby causing material to be electroerosively removed from the workpiece W.

As material removal proceeds, a worktable 12 on which the workpiece W is securely mounted is displaced in an X—Y plane by means of a pair of motors 13 and 14, e.g. stepping motors, designed to move the worktable 12 along an X-axis and a Y-axis, respectively. A numeral-control (NC) unit 15 is provided to furnish preprogrammed drive signals to the motors 13 and 14, thereby displacing the workpiece W along a predetermined path and thus forming in the workpiece a desired wire-cut contour defined by the displacement path of the workpiece.

In accordance with the present invention, a coil 16 is provided and energized by a power supply 17. The wire electrode 1 is, as shown in FIG. 2, constituted by a wire 1*a* of a high-tensile strength and magnetic (e.g. magnetically permeable or conductive) material and having an outer layer 1*b* of good electrical conductivity. Since the core material 1*a* is high in tensile strength, the entire diameter or thickness of the wire electrode 1 can be substantially reduced as compared with conventional electroerosion wire electrodes, and a greater tension can be applied to eliminate the possibility of wire loosening. For example, a sintered and drawn ferrous wire of a diameter of 0.1 mm can be a suitable core material 1*a* and can have a layer of a thickness of 0.05 mm of copper coated thereon by electrodeposition. The resulting wire electrode of an overall diameter of 0.2 mm is found to be several times greater in tensile strength than a usual copper wire electrode of the same diameter for wire-cutting electroerosion. The composite wire electrode according to the invention allows the rate of axial displacement to be substantially reduced, hence permitting the amount of material consumption to the markedly reduced, as compared with the conventional wire electrode of similar electric conductivity.

A modification of the wire electrode 1 according to the invention may, as shown in FIG. 3, be a combination of the magnetic core member 1*a* with two electrically conductive layers 1*b* and 1*c*. For example the core member 1*a* may be a wire of 0.1 mm diameter of magnetic stainless steel prepared by drawing at room temperature; the inner electrically conductive layer 1*b* may be composed of copper deposited to a thickness of 0.05 mm on the core member 1*a* and the outer electrically conductive layer 1*c* may be composed of gold deposited to a thickness of 0.05 mm on the inner layer 1*b*. In an alternative embodiment, the magnetic stainless steel wire 1*a* may be of a diameter of 1.5 mm, the inner copper conductive layer 1*b* may be of a thickness of 0.03 mm and the outer conductive layer 1*c* may be of a thickness of 0.02 mm. These composite wires have been found to permit the rate of axial displacement to be markedly reduced and at the same time to possess extremely good electrical and thermal conducting and erosion-resistant properties.

The magnetic field generated by the assembly 16 should preferably be of an intensity in excess of 100 Gauss. The magnetically conductive core wire 1*a* provides a path for the magnetic fluxes which appear to interact with the machining or discharge

current passed through the machining gap formed between the workpiece W and the conductive portion 1*b* (or 1*b* and 1*c*) of the wire electrode 1 in the manner to yield highly favorable machining results. It has been observed that the interaction facilitates the gap breakdown, effectively extends the gap spacing and enhances the rate of repetition of machining discharges. The machining chips and other gap products are thus carried away from the machining gap with an increased facility which promotes the renewal of the machining liquid in the gap region and hence permits the workpiece to be cooled at an increased rate. The machining discharges are allowed to be repeated consecutively with less tendency towards a detrimental arcing and short-circuiting. The machining liquid renewed at an increased rate also facilitates the cooling of the wire electrode and thus prevents it from over-heating due to a high-amperage machining current passage, accordingly reducing the wire breakage to a minimum and permitting the cutting process to proceed with an increased stability and to yield the machined workpiece with an improved surface finish and precision.

The coil 16 is preferably located in the vicinity of the machining gap or the region of cutting zone 4 and is disposed so as to surround the wire electrode 1. The magnetic field produced by the coil 16 and hence the output of the power supply 17 for energizing the coil 16 is either of AC or DC nature and either continuous or pulsed. The pulsed or AC magnetic field is, however, preferred. With pulsed or alternating magnetic fluxes, it has been observed that the machining chips and other gap accumulations undergo random movements and are carried away from the gap region with an increased facility. Further, the random and dispersive production of machining discharges along the machining surfaces is promoted, tending to eliminate a possible arcing or short-circuiting and thus permitting material removal to progress with an enhanced efficiency and stability.

More than one coil 16 may be arranged, such coils being energized in phase or out of phase with one another, as desired, by common power supply 17. One coil may be disposed at one side of the cutting zone 4 and another coil at the opposite side thereof with respect to the workpiece W.

The coil or coils 16 (with the associated power supply 17) may be replaced by a permanent magnet or magnets adapted to produce the equivalent magnetic field of an intensity preferably not less than 100 Gauss.

There are thus provided, in accordance with the present invention, an improved method of and apparatus for electroerosively wire-cutting a workpiece whereby improvements are achieved as regards both cutting efficiency and stability.

CLAIMS

1. A method of electroerosively wire-cutting a workpiece with a continuous elongate electrode axially displaced from a supply side to a takeup side through a cutting zone of the workpiece flushed with a machining liquid, wherein an electric machining current is passed between the traveling elongate electrode and the workpiece through a machining gap to electroerosively remove material from the workpiece while a relative displacement other than the axial displacement of the elongate electrode is effected between the latter and the workpiece along a prescribed path to form a desired wire-cut pattern in the workpiece, and wherein:—

(a) said elongate electrode is constituted by a wire composed of a magnetic material and having a layer of an electrically conductive material disposed thereon; and

(b) a magnetic field is applied to the region of said machining gap.

2. The method defined in claim 1 wherein said magnetic material is of a tensile strength greater than that of said electrically conductive material.

3. The method defined in claim 2 wherein said magnetic material is of an electrical conductivity less than that of said conductive material.

4. The method defined in any preceding claim wherein said conductive material is selected from the group which consists of copper, silver, aluminium and gold and alloys containing at least one of them.

5. The method defined in claim 1 or claim 2 wherein said magnetic material is a ferrous material.

6. The method defined in claim 5 wherein said magnetic material is a stainless steel.

7. The method defined in any preceding claim wherein said magnetic field is of an intensity not less than 100 Gauss.

8. An apparatus for electroerosively wire-cutting a workpiece with a continuous elongate electrode, which apparatus includes drive means for axially displacing the elongate electrode from a supply side to a takeup side through a cutting zone of the workpiece while applying a tension to the elongate electrode traveling across the cutting zone, means for flushing the cutting zone with a machining liquid, power supply means for passing an electrical machining current between the elongate electrode and the workpiece through a machining gap formed therebetween to electroerosively remove material from the workpiece, and machining feed means for effecting a relative displacement between the traveling elongate electrode and the workpiece along a prescribed path to form a desired wire-cut pattern in the workpiece, and in which apparatus:—

(a) said elongate electrode is constituted by a wire composed of a magnetic material and having a layer of an electrically conductive material disposed thereon, and

(b) there is provided a means for applying a magnetic field to the region of said machining gap.

9. The apparatus defined in claim 8 wherein said means for applying the magnetic field comprises at least one coil means energizable by a power supply for producing the said magnetic field of an intensity not less than 100 Gauss.

10. The apparatus defined in claim 9 wherein said at least one coil means includes a coil disposed to surround said elongate electrode.

11. The apparatus defined in claim 10 wherein said coil is disposed in the region of said cutting zone.

12. The apparatus defined in claim 8 wherein said means for applying the magnetic field comprises at least one permanent magnet adapted to produce the said magnetic field of an intensity not less than 100 Gauss and disposed in the region of said cutting zone.

13. The apparatus defined in any one of the claims 8 to 12 wherein said magnetic material is of a tensile strength greater than that of said electrically conductive material.

14. The apparatus defined in claim 13 wherein said magnetic material is of an electric conductivity less than that of said conductive material.

15. The apparatus defined in any one of the claims 8 to 14 wherein said conductive material is selected from the group which consists of copper, silver, aluminium and gold and alloys containing at least one of them.

16. The apparatus defined in any one of the claims 8 to 12 wherein said magnetic material is a ferrous material.

17. An apparatus as defined in any one of the claims 8 to 16, substantially as hereinbefore described with reference to, and as illustrated by the accompanying drawings.

18. A method as defined in any one of the claims 1 to 7, substantially as hereinbefore described with reference to the accompanying drawings.

19. A workpiece machined by a method as defined in any one of the claims 1 to 7 and 18, or by means of an apparatus as defined in any one of the claims 8 to 17.

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